

Casting a Wide Net via Case Studies: Educating across the undergraduate to medical school continuum in the biological sciences

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Abstract

This article seeks to help bridge undergraduate and medical educators by describing shared educational goals and strategies, highlighting resources relevant for both groups, and exemplifying shared interests through a demonstration resource. Both undergraduate and medical educators are interested in increasing student engagement with scientific content, and a widely used approach to accomplish this goal is case-based discussion. Using case studies promotes active learning and deeper understanding of the content. In the highlighted cases focusing on the intersection of genetics and ethics, these advantages are particularly apparent, as the application of genetic principles and approaches to clinical care is a nuanced challenge that requires careful consideration of the ethical implications for patients and stakeholders. These cases can be adapted to focus on science, its clinical applications, ethical and philosophical dimensions, or on all of the above. Medical students found these cases to be very stimulating and eye-opening. Comments from students indicated that they appreciated the opportunity to grapple with the ethical dimensions of the genetic testing technologies, and that the challenges brought to light highlighted the complexity of ethical scenarios in genomic medicine on which even the experts disagree. Although these cases were initially developed for use with first year medical students, given the range of topics they encompass, they can easily be adapted to generate appropriate learning goals for a variety of learning communities and educational settings including science, social science, and humanities courses at the undergraduate, graduate, professional school, post-graduate, and continuing education levels.

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Learning Goal(s)

How does genetics impact society and society impact genetics?

Learning Objective(s)

Students will be able to:

- Consider the potential advantages and disadvantages of widespread use of whole genome sequencing and direct-to-consumer genetic testing.
- Explore the critical need to maintain privacy of individual genetic test results to protect patient interests.
- Dissect the nuances of reporting whole genome sequencing results.
- Recognize the economic ramifications of precision medicine strategies.
- Formulate a deeper understanding of the ethical dimensions of emerging genetic testing technologies.

INTRODUCTION

In the biological sciences, it is very common for students to build upon their undergraduate studies through pursuit of advanced degrees. As such, educational missions and objectives for undergraduate students majoring in biology and medical and graduate students often overlap¹. Both communities have an increasing focus on interdisciplinary science, active learning methods, and on ensuring that the biology taught in the classroom mirrors the biology practiced by professionals (2–5). In spite of these shared goals, the communities of educators frequently remain quite distinct from one another.

Educators of biology undergraduates and medical students have separate peer-reviewed clearinghouses for disseminating teaching resources, including CourseSource⁶ and the National Center for Case Study Teaching in Science (7) at the undergraduate level and MedEdPORTAL (8) for medical students, resident physicians, and other health professional trainees. In this Teaching Tools and Strategies essay, I describe the adaptation of a series of ethics cases (9) developed for use in discussion sessions with first year medical students that can easily be tailored for use with undergraduate students in the biological sciences, in interdisciplinary courses examining the intersection of science, philosophy, and ethics, or in science writing courses.

The cases themselves are designed to engage the learner and illustrate how the relevant science and technology impact the students, patients, and families they are meant to assist. Materials included in the educational resource (9) provide the context for the professor to set the stage with relevant background information and to present the cases to the students. Suggested discussion questions are also included, and teaching notes are provided to facilitate the discussion. The overall goals of this lesson allow learners to consider the potential advantages and disadvantages of widespread use of whole genome sequencing and direct-to-consumer genetic testing, to dissect the nuances of reporting whole genome sequencing results, to explore the critical need for privacy to protect patient interests, and to recognize the economic ramifications of precision medicine strategies all while considering the ethical context of these rapidly evolving technologies.

SCIENTIFIC TEACHING THEMES

Active learning

The highlighted educational resource (9) is specifically designed to facilitate active learning of the concepts at the intersection of genetics and ethics in a variety of classrooms. This is accomplished by providing a series of cases along with instructor question prompts that serve as the basis for student exploration of the scientific and ethical concepts introduced in the cases. By working in groups, the students have the opportunity to actively consider potential answers by listening to their peers and by contributing to the discussion. The discussion cases were used in large classrooms, encouraging widespread engagement with the material via a think-pair-share model. The clicker questions also engaged the students in the large enrollment setting, and they allowed students to anonymously contribute to complex, sometimes philosophical questions.

Assessment

Because this resource addresses complex ethical concepts, it doesn't typically fall into the type of science content that can be assessed by questions with clear right and wrong answers. Rather, the act of engaging with the content through discussion or writing assignments is the recommended way to assess student understanding of these nuanced concepts. When these cases were used in a large enrollment medical school class, students were given credit for engaging in group discussions, and the content related to professional recommendations for clinicians appeared on individual multiple choice assessments. In terms of success of this approach, student evaluation comments are included that provide their perspectives on this activity.

Inclusive teaching

Because this resource examines the complexities of using genetic technologies, a diversity of perspectives is a valuable element to incorporate into the discussions. Indeed, if learners approached these cases with a single point of view, the discussion itself would not be as successful in examining multiple viewpoints on these cases. With respect to the clicker questions in particular, sample compiled data⁹ demonstrate that a range of opinions were offered by first year medical students, which in terms of professional focus, might be considered a relatively homogenous group. However, they still revealed a range of views on these complex issues, as was also seen in the classroom discussion cases.

Importantly, the case collection also addresses racial and ethnic diversity with the introduction of a case that examines the differences between precision medicine based on genetic predisposition versus health care decisions based on racial categorization.

LESSON PLAN

Introduction

As our understanding of the genetic basis of human disease has grown, genetic testing applications for these conditions have grown in parallel (10,11). Discussion of the nuances of these testing strategies in the context of direct-to-consumer genetic testing, identification of secondary findings in genomic strategies, and other ethically complex scenarios is imperative for scientists and physicians to fully consider responsible use of genomic technologies (12–14).

Although general frameworks for ethics in the practice of medical genetics have been proposed (15–17), with the development of new genetic and genomic technologies have come new specialized cases requiring application-specific ethical analysis. For instance, the American College of Medical Genetics and Genomics has systematically provided clinical and ethical guidance on genetic testing in the context of direct-to-consumer genetic testing (18), noninvasive prenatal screening (19), and clinical exome and genome sequencing (20) especially as it pertains to reporting of secondary findings (21,22) and informed consent (23). Notably, experts in the field do not uniformly support these recommendations (24), indicating that simply memorizing a group of practice guidelines is not sufficient. Rather, trainees in the natural sciences will need to be comfortable grappling with the ethical implications of the genomic technologies they will be developing and using in the clinic so as to adapt in this

rapidly evolving field.

This particular collection of cases in MedEdPORTAL (9) aims to delve into these emerging areas in genomic medicine and provide educational tools to encourage critical thinking and analysis of the scientific, ethical, legal, and social implications of these genomic technologies. Furthermore, the case collection includes facilitator teaching notes, a student handout, and a slide presentation to aid in implementation in the classroom. These materials are available to the general public at no cost upon registration with a free AAMC account.

These cases were used at the Boston University School of Medicine beginning in 2004. The content was discussed annually in a Medical Genetics (2004 – 2015) or Principles Integrating Science and Medicine (2016 – present) course for first year medical students, with the addition of new cases as the field progressed. The cases were used both in the context of a class period with a focus on ethics and were injected into class periods otherwise focusing mainly on foundational science. Thus, the cases can be used both in the context of classes focused on science or on ethics. By implementing some or all of these cases, instructors can promote high level discussion of the ethical complexities arising in the genomic era from a variety of perspectives, both scientific and otherwise.

Instructional Methods

Materials

The cases are provided in two groups in the MedEdPORTAL publication (9): discussion cases and clicker questions. Instructor notes covering the scientific and ethical dimensions of the cases are also provided at that website. Elements of the cases and discussion themes are summarized in Table 1.

Length

If an instructor is planning to use the full set of discussion cases in one class period, two hours of class time is recommended. However, the cases are independent and can be distributed among multiple class periods or among multiple student groups in a shorter class period. The cases in this collection have been used both throughout an integrated foundational sciences curriculum, as the topics were introduced by the author, and in a single special class period focusing on ethics. Depending on the context in which these cases are introduced, the relevant science, ethical principles, or both can be the emphasis of the discussion. For logistical considerations of case study and question use, please see Table 2.

Creating a safe space for discussion

Discussion of these cases does require some comfort on the part of the learners to discuss potentially controversial issues in a classroom setting. For this reason, we recommend use of anonymity preserving techniques (such as audience response systems) or small groups to create a safer space for discussion of potentially sensitive issues.

Results

We successfully implemented the discussion cases in our class of 180 first year medical students. Notably, student opinions for these cases were wide-ranging (9), which allowed for in-depth discussion of contrasting viewpoints and

highlighted the need for discussion of these complex topics among both students and experts. This framework served as an excellent launching point to allow students to break into smaller groups within the lecture hall to compare their perspectives on these issues and then share their views with the larger student group.

Student engagement with the material presented in the cases was high, and they raised many complex points. There was rich discussion on the influence of for-profit genetic testing companies, the nature of secondary findings, and the limited preventative options available in genetic conditions. Feedback from course evaluations was strongly positive, and representative quotes are included below.

Representative Course Evaluation Comments

- [The professor] recognized the relevance of race, ethnicity, sexuality, and cultural difference on what she/he was teaching, and...addressed these topics in a respectful way that enhanced our overall understanding of the material and our ability to provide good care to diverse patient populations. This course should provide the standard for teaching diversity in our other courses.
- I really appreciated how [the professor] brought in real-world applications of the material and pushed us to think about the issues that we will face in our practice of medicine.
- Small group discussions between students were always engaging as they touched on ethics, future technology, and prompted us to reflect on our value systems & future practice.
- [The professor] has done a great job in organizing this course the topics were relevant and the information was current and genetics as a social, political, ethical issue was also covered which was really informative.
- The repeated references to the socioeconomic considerations around testing, screening, and access were greatly appreciated as a way to tie the knowledge to the clinical and societal applications/implications of genetic medicine.
- The best section of the course for me was the lecture on the historical and emerging issues in ethics in genetics, and I think the points brought to light are very real challenges most of us will encounter in the future in practice.
- ...it's been one of my favorite classes thus far. A lot of that has to do with how [the professor] emphasized the fact that medical genetics is fraught with ethical issues that force us to consider what it truly means to be human – one of the fundamental questions that got me interested in medicine in the first place.

TEACHING DISCUSSION

This case collection represents a versatile pedagogical resource in that it is easily adaptable to multiple curriculum structures, settings, trainee levels, and academic disciplines. These discussion cases can be reimagined in many ways because of the flexibility of the approaches that allow active engagement with the content. They can be used in small classrooms, in lecture halls for a large group discussion, or in large classrooms dividing the students into smaller groups as with think-pair-share or team-based learning. Furthermore, the question prompts accompanying the cases were created to aid in-class discussion but can also potentially serve as writing

prompts for essay assignments or for use with discussion boards in on-line courses. The clicker questions also lend themselves well to classroom debates by encouraging students to take a position and then defend it as a group. The strength in these cases is their versatility and adaptability to a wide range of educational environments.

The trainees at Boston University School of Medicine were very engaged with the complex concepts introduced by these cases, which reflect issues they will face in their future clinical practice and which mirror interests of pre-health students at the undergraduate level as well. I have successfully deployed this collection of cases over the past 13 years, adapting the content to the evolving developments in the field of genomic medicine. As technology has progressed, ethical issues warrant further discussion, and medical students have demonstrated significant engagement with this content, particularly as it frequently appears in popular media. For this reason, it is likely to also capture the interest of undergraduates, whether they are studying the sciences, social sciences, philosophy, or other areas. Moreover, interdisciplinary courses with students from multiple groups will have especially rich environments in which to explore this topic. Indeed, one of the areas of future expansion for materials like these in the medical education setting is interprofessional education; at the undergraduate level, it is possible to take this one step further and involve individuals not only with interests in the allied health professions, but also future scientists, philosophers, ethicists, lawyers, economists, and public servants. For example, to capitalize on an interdisciplinary undergraduate environment, it would be an interesting exercise to guide the students through development of proposed practice guidelines in these areas to grapple on a deeper level with the principles governing the composing of professional guidelines in deploying a transformative technological innovation.

As institutions of higher education embrace more active forms of learning (2–5), this type of activity would support overarching goals to encourage in-depth experiences with content, particularly in the context of the rapidly evolving fields of precision and genomic medicine.

SUPPORTING MATERIALS

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Table 1. Medical Case Studies - Summary of the elements of the cases and discussion themes

Case or Question	Description	Time	Discussion Themes
Discussion Cases			
1. Cystic Fibrosis testing	One parent does not have a readily-identifiable CF mutation although child is affected with recessive disorder.	5-10 minutes	Patient privacy and confidentiality, misattributed paternity, cascade genetic testing
2. Direct-to-consumer tests in college	Incoming college freshmen are offered free genetic testing in absence of genetic counseling as a class project.	10-15 minutes	Role of genetic counselors, genetic testing of minors, coercion and payment for testing
3. Advertising BRCA1 and BRCA2 testing	Testing company creates ad campaign targeting patients directly and primary care physicians.	10-15 minutes	Interpretation of genetic testing results, variants of unknown significance, Supreme Court case on patenting genes
4. Consumer genetic tests for athletic ability	Recreational genetics company creates test that promises to indicate best sports match for people of different genotypes.	5-10 minutes	Genetic testing of minors, non-essential / lifestyle genetic testing
5. The Nash family	Parents of a child with Fanconi Anemia choose to have a second child, selected for by preimplantation genetic diagnosis, who will be a match and subsequent stem cell donor for his sister.	10-15 minutes	Child conception for tissue donation, insurance coverage vs. private payment of preimplantation genetic diagnosis costs, ethics of regenerative medicine using stem cells
6. Burlington Northern Santa Fe Railroad	Company physicians treating employees carry out genetic testing without knowledge of patient to ascertain genetic risk of a familial syndrome that mimics on-the-job repetitive stress injury.	10-15 minutes	Informed consent, privacy of genetic information, Genetic Information Nondiscrimination Act (GINA)
7. Sickle cell anemia population testing	Race-based population screening initiative in 1970s whereby sickle cell status was used to inform employment decisions.	10-15 minutes	Rationale behind population screening, privacy of genetic information, Genetic Information Nondiscrimination Act (GINA)
8. Nitromed and BiDil	Medication was repurposed as race-based therapy after clinical trial data showed higher efficacy among African American patients just as original patent was expiring.	10-15 minutes	Differences between race, geographic ancestry, and genetic predisposition; patent system
9. Cassidy v. Smith Kline Beecham	Company developed a vaccine for Lyme disease that caused individuals of a known specific genotype to experience an adverse reaction.	10-15 minutes	Pharmacogenetic testing, economics of bringing drugs and vaccines to market
10. The Pseudo Xanthoma Elasticum patent	Families band together with scientists to help identify the gene causing a severe connective tissue disorder and share ownership of the patent.	5-10 minutes	Patenting of genetic inventions, patient funding
11. The Newborn Sequencing in Genomic Medicine and Public Health (NSIGHT) Project	Full exome sequencing of both healthy and sick infants is initiated in BabySeq project.	10-15 minutes	Informed consent, incidental findings in whole exome sequencing, right not to know, duty to recontact, sequencing of minors
Clicker Questions			
Value of direct-to-consumer testing	Students are asked to consider place of direct-to-consumer testing in landscape of genetic testing.	5 minutes	Recreational genetics vs. clinical genetics
Reporting of whole exome sequencing findings	Students weigh benefits of reporting different categories of genetic findings.	5 minutes	Carrier status, affected status, age of onset
Clinical whole genome sequencing	Students discuss the appropriate scope and venue for offering this testing	5 minutes	Clinical testing by specialists vs. generalists, actionable findings
Mitochondrial manipulation	Students dissect the implications of mitochondrial manipulation for the patient and future generations	5 minutes	Transmissible genetic modification, maternal inheritance
Genetic testing for motor control	Students consider the competing interests of ensuring customer safety vs. employee discrimination.	5 minutes	Privacy of genetic information, Genetic Information Nondiscrimination Act (GINA)

Table 2. Medical Case Studies - Logistics of case study and clicker question use

Activity	Description	Time	Notes
Prepare handouts	If engaging in small group discussion, preparation of handouts for the student groups is advised.	10 minutes	The handout is provided as a supplemental file in the original publication; it simply requires copying.
Discussion of full case set	If using the discussion cases in a single class session, the full range of topics can be included.	2 hours	
Discussion of individual cases	These cases can also be sprinkled throughout related lessons.	10-15 minutes per case	These can be expanded in time if distributed among student groups for presentation purposes.
Use of clicker questions	These questions can be sprinkled throughout related lessons.	5-10 minutes per question	This timeframe would allow collection of responses as well as discussion of differing answers. To use the audience response approach, the appropriate technology would need to be available in the classroom.